

F61: Nuclear Magnetic Resonance

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Abstract

In Protocoll we will examine the usage nuclear magnetic resonance to identify probes and reveal the structure of objects.

1 Basics

1.1 Basics of Nuclear Magnetic Resonance

Nuclear Magnetic Resonance techniques relay of the interaction between the magnetic dipole moment

$$\vec{\mu} = \hbar\gamma\vec{S} \quad (1)$$

of nuclei with non-zero spin S and an external magnetic field \vec{B}_0 . In the following paper γ represents the gyromagnetic ratio of protons:

$$\gamma_{proton} = 2.6752 \cdot 10^8 \text{ sec}^{-1} \text{ Tesla}^{-1}. \quad (2)$$

The resulting interaction energy is defines as:

$$\Delta E = -\vec{\mu} \cdot \vec{B}_0. \quad (3)$$

In a classical description, this interaction yields two states for the orientation of the protons's magnetic dipole in the external magnetic field: μ_+ (parallel) and μ_- (antiparalle). For a macroscopic sample of N protons, both numbers of occupied states N_+ and N_- , the sum of which comprises N , can be approximated by a Boltzmann distribution:

$$N_{\pm} = N_0 e^{-\frac{E_0 \pm \Delta E}{kt}} \quad (4)$$

with N_0 as a normalization factor. However $N_+ > N_-$, since the parallel state is energetically favorable. The predominance of protons in the parallel

state leads to a macroscopic magnetization, whose ground state is

$$\vec{M}_0 = \frac{\mu N}{V} \sinh\left(\frac{\mu B}{kT}\right) \vec{e}_z. \quad (5)$$

In our case, a weak field ($\mu B \gg kT$), the former expression simplifies to

$$\vec{M}_0 = \frac{N}{V} \frac{\hbar^2 \gamma^2 I(I+1)}{3kT} \vec{B}_0 \propto \frac{\vec{B}_0}{T}, \quad (6)$$

i.e the law of Curie.

In general, the magnetization can have a macroscopic state characterized by \vec{M}_0 minimizes the energy.

1.2 NMR signal

1.3 Relaxation Time

1.4 Chemical shift

2 Measurements

3 Analysis

4 Critical Discussion